US009844130B2

(12) **United States Patent**
**Ikeda et al.**

(10) **Patent No.: US 9,844,130 B2**
(45) **Date of Patent: Dec. 12, 2017**

(54) **PACKAGE FOR OPTICAL SEMICONDUCTOR DEVICE**


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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/391,053**

(22) Filed: **Dec. 27, 2016**

(65) **Prior Publication Data**

US 2017/0202081 A1 Jul. 13, 2017

(30) **Foreign Application Priority Data**

Jan. 8, 2016 (JP) ................................ 2016-002347

(51) **Int. Cl.**

| | |
|---|---|
| ***H05K 1/00*** | (2006.01) |
| ***H05K 1/02*** | (2006.01) |
| ***H01L 31/0203*** | (2014.01) |
| ***H01L 31/02*** | (2006.01) |
| ***H05K 1/11*** | (2006.01) |
| ***H01S 5/022*** | (2006.01) |
| ***H01S 5/18*** | (2006.01) |

(52) **U.S. Cl.**
CPC ....... ***H05K 1/0274*** (2013.01); ***H01L 31/0203*** (2013.01); ***H01L 31/02005*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ...... H05K 1/115; H05K 1/274; H01L 23/495; H01L 23/498; H01L 31/203;
(Continued)


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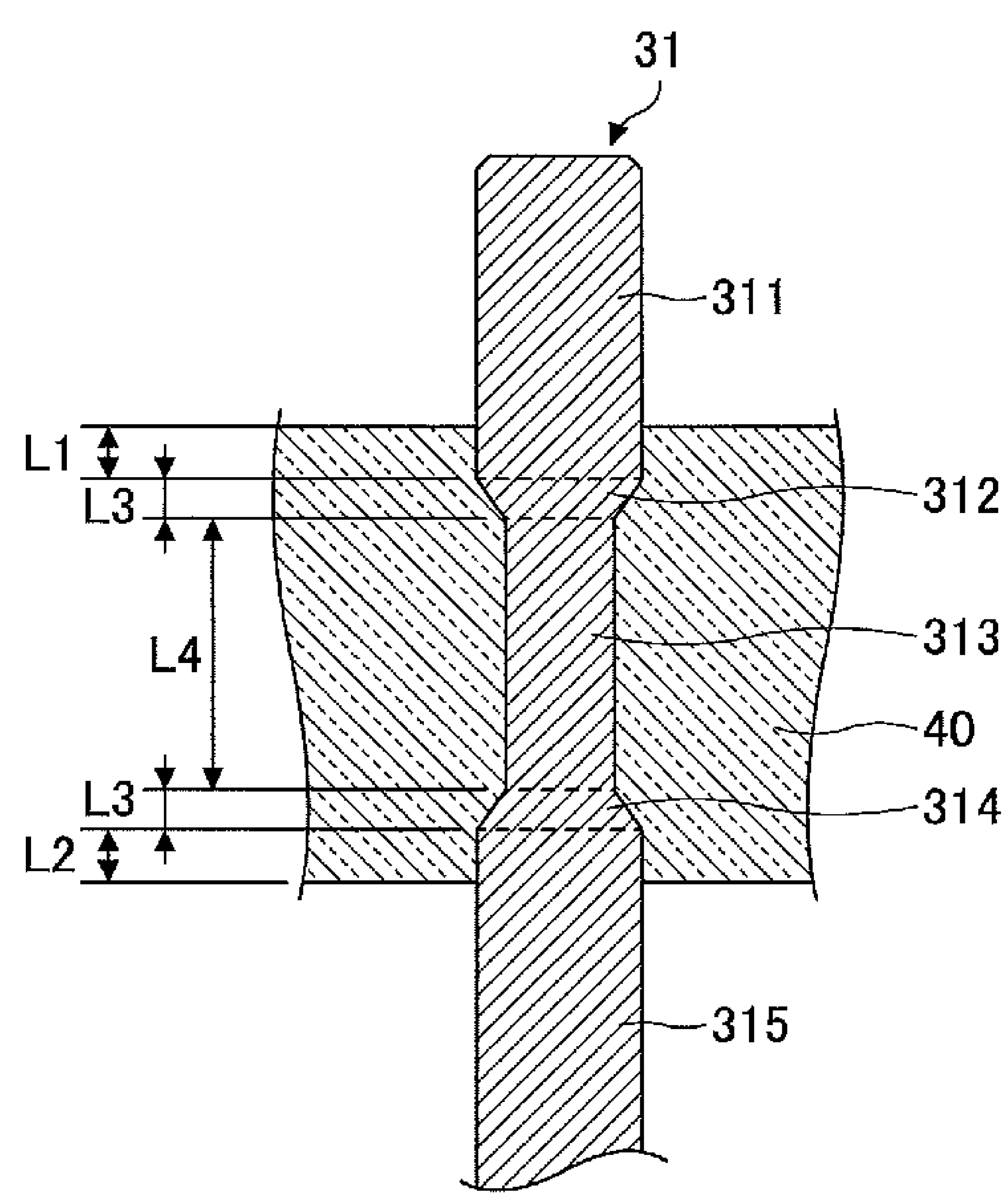
(57) **ABSTRACT**


A package for an optical semiconductor device includes an eyelet, a signal lead inserted in a through hole formed in the eyelet, and sealing glass sealing the signal lead in the through hole. The signal lead includes a first portion, a second portion and a third portion that are greater in diameter than the first portion and on opposite sides of the first portion, a first tapered portion extending from the second portion to the first portion, and a second tapered portion extending from the third portion to the first portion. The first portion and the first and second tapered portions are buried in the sealing glass. The total length of a part of the second portion in the sealing glass and a part of the third portion in the sealing glass is 0.2 mm or less.


**5 Claims, 6 Drawing Sheets**



(52) **U.S. Cl.**
CPC ............ ***H01S 5/02256*** (2013.01); ***H01S 5/18*** (2013.01); ***H05K 1/115*** (2013.01); *H05K 2201/095* (2013.01)

(58) **Field of Classification Search**
CPC ......... H01L 31/2005; H01S 3/00; H01S 5/18; H01S 5/22; H01S 5/2256
USPC ...... 174/258; 257/81, 82, 99, 433, 666, 676, 257/691; 206/316.1
See application file for complete search history.

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FIG.1A

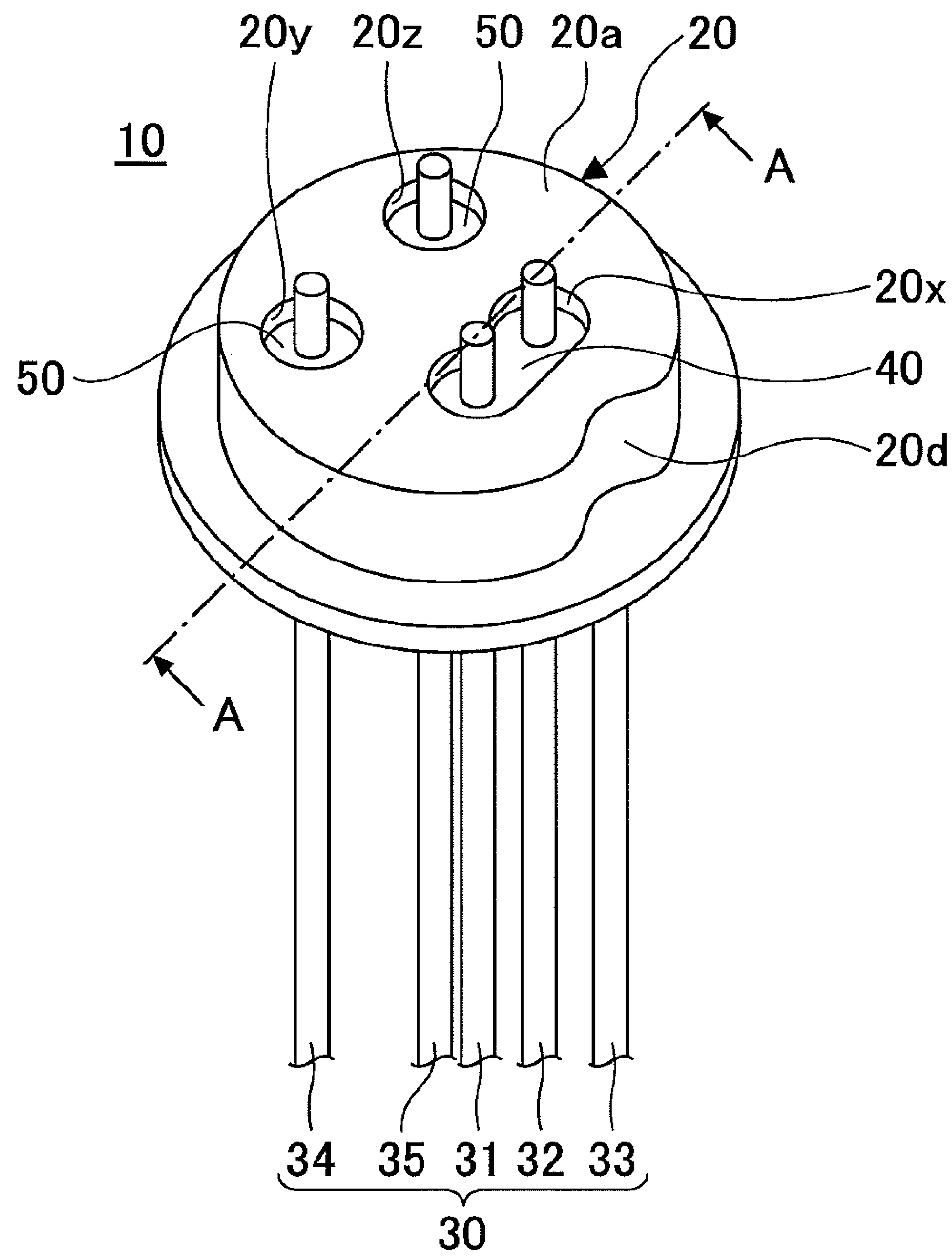

10
20y
20z
50
20a
20
A
20x
40
50
20d
A
34
35
31
32
33
30

FIG.1B

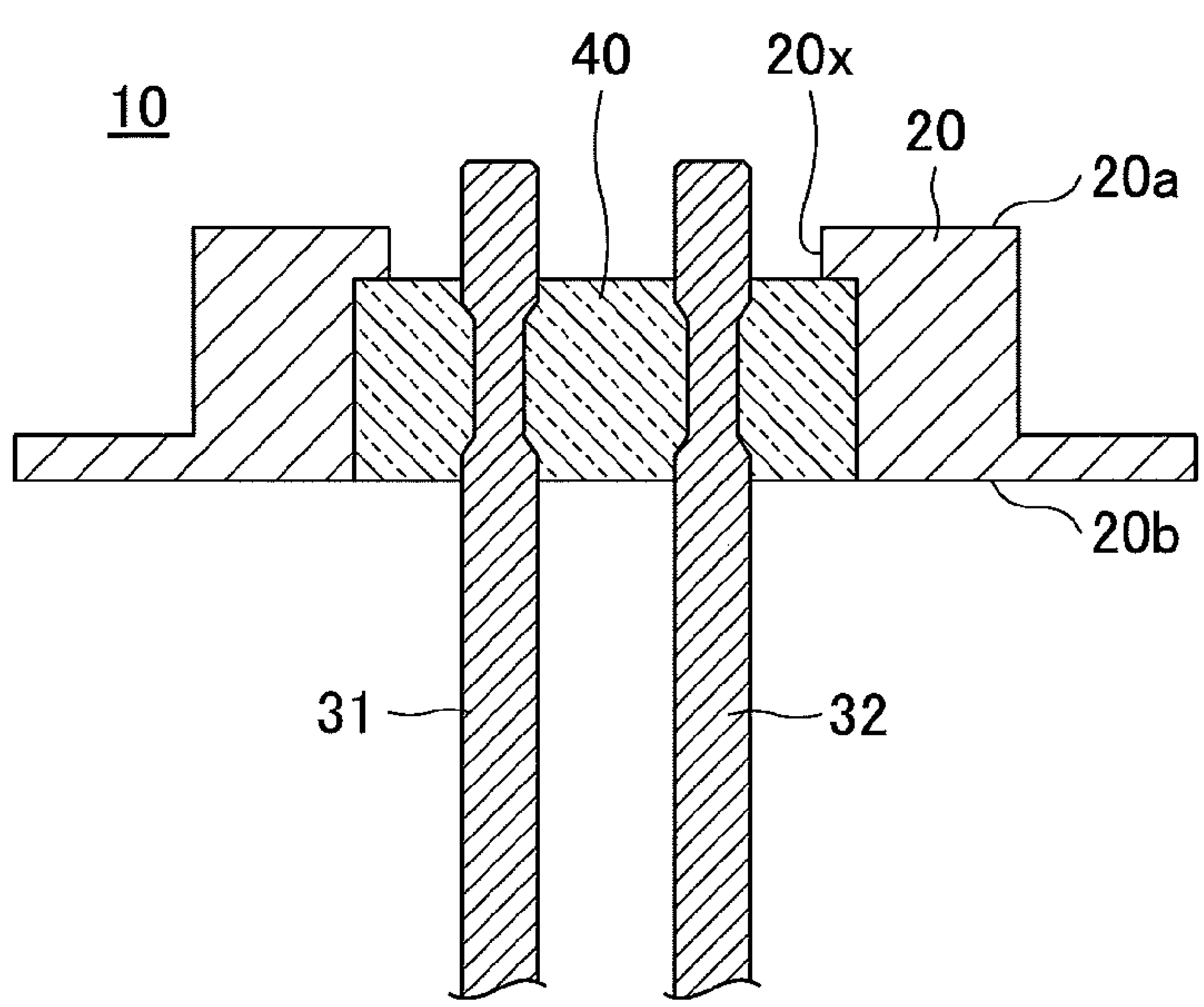
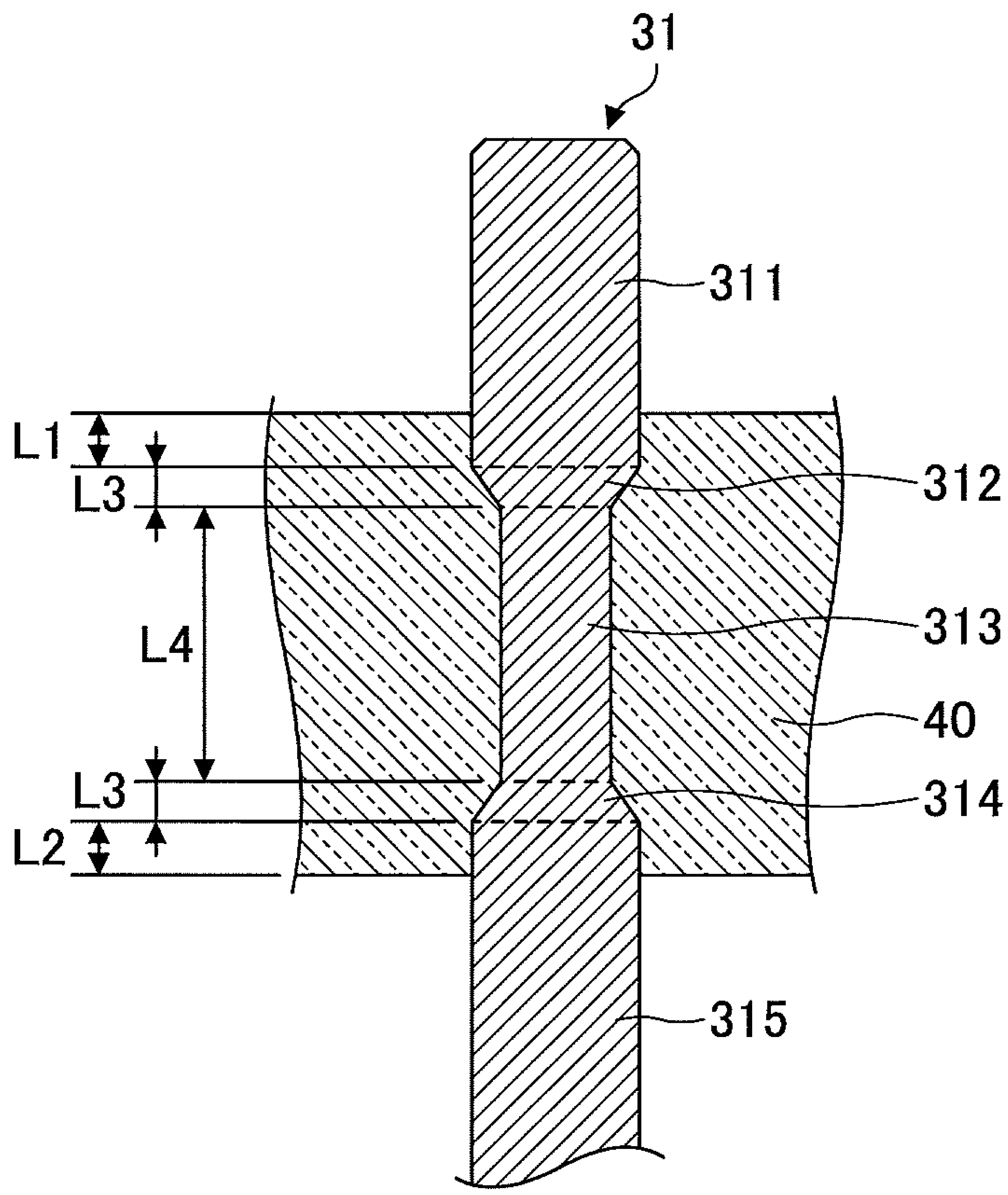

10
40
20x
20
20a
20b
31
32

FIG.2



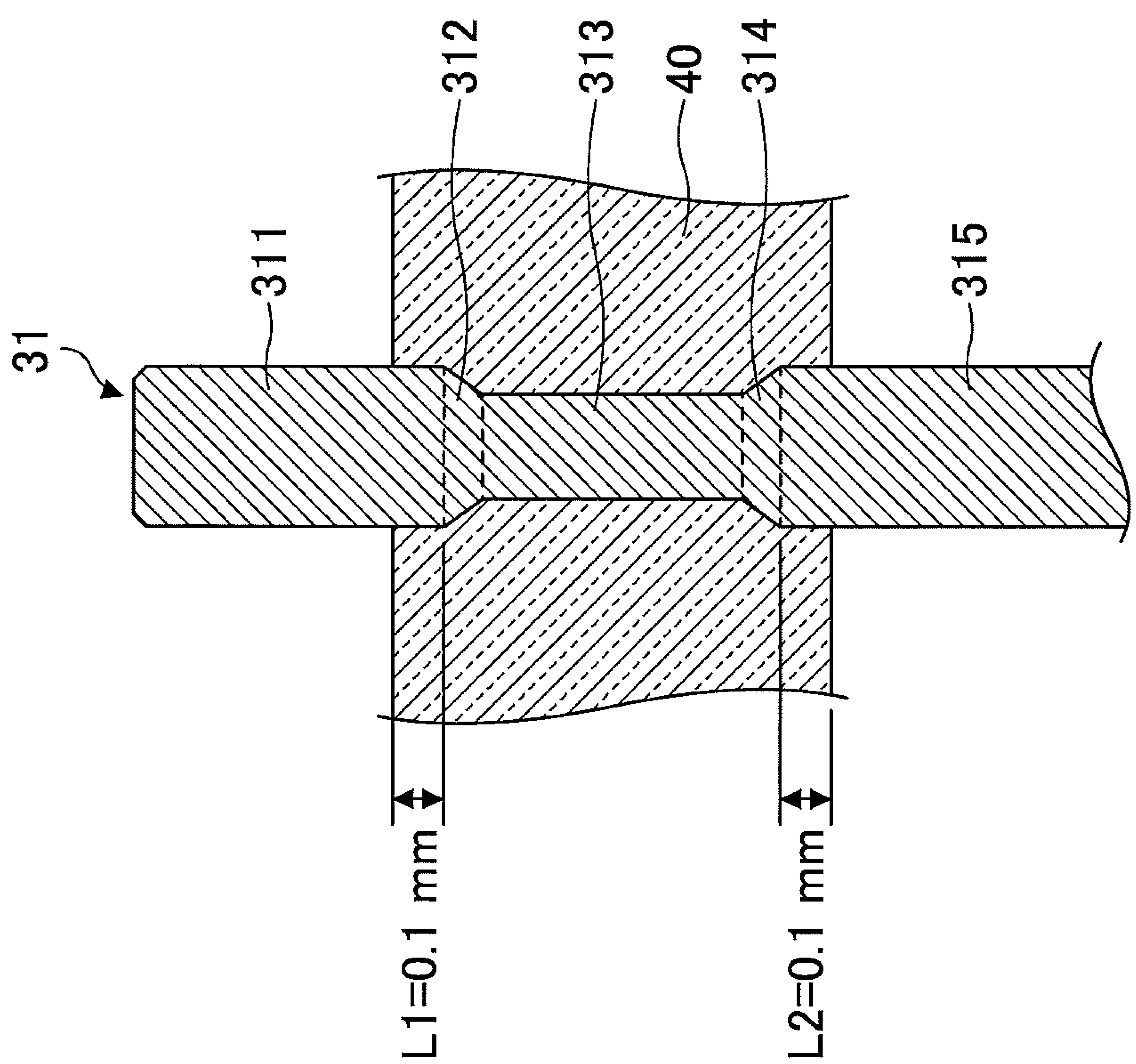

31
311
312
313
40
314
315
L1=0.1 mm
L2=0.1 mm

FIG.3A

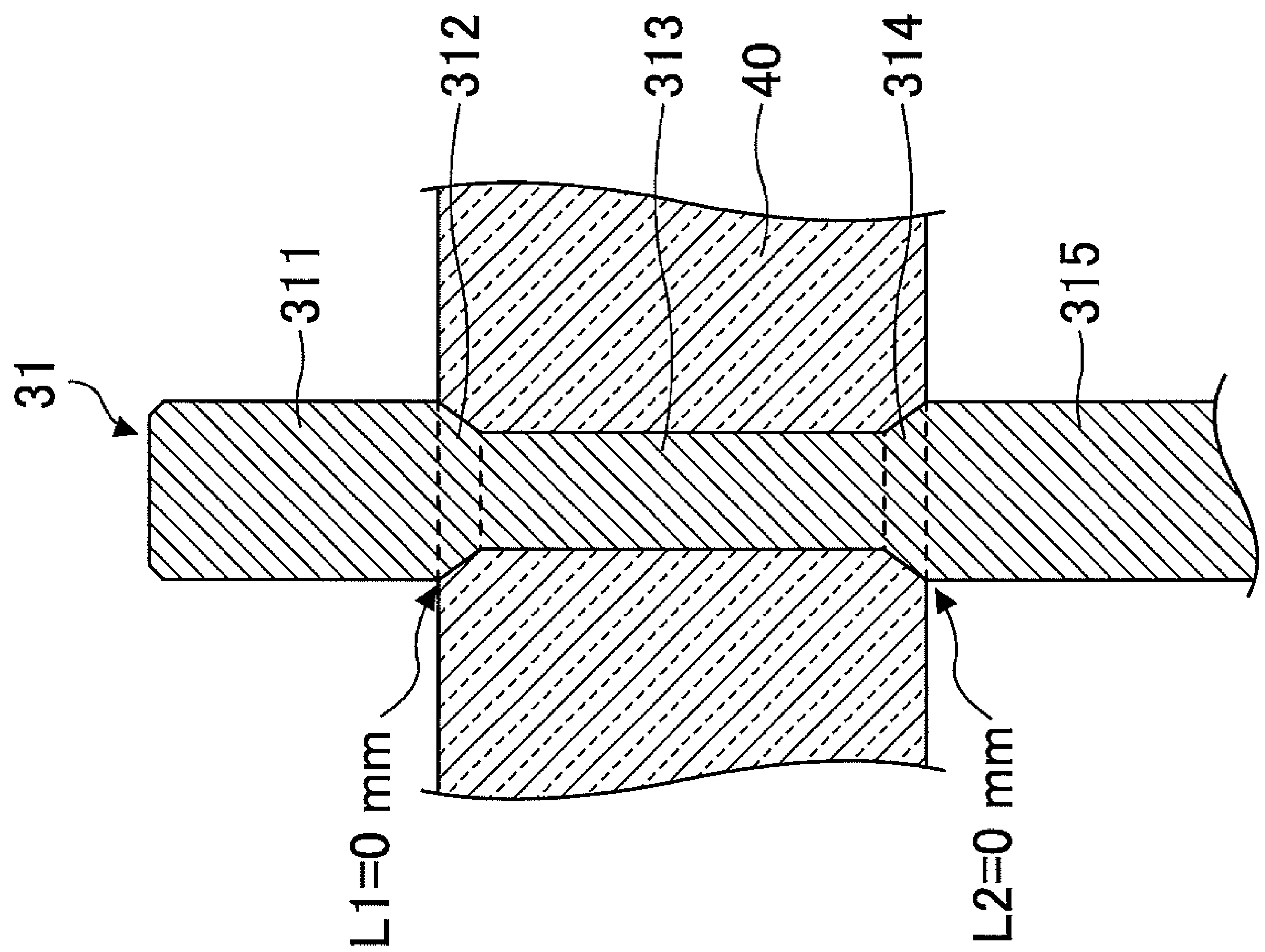

31
311
312
313
40
314
315
L1=0 mm
L2=0 mm

FIG.3B

FIG.4A

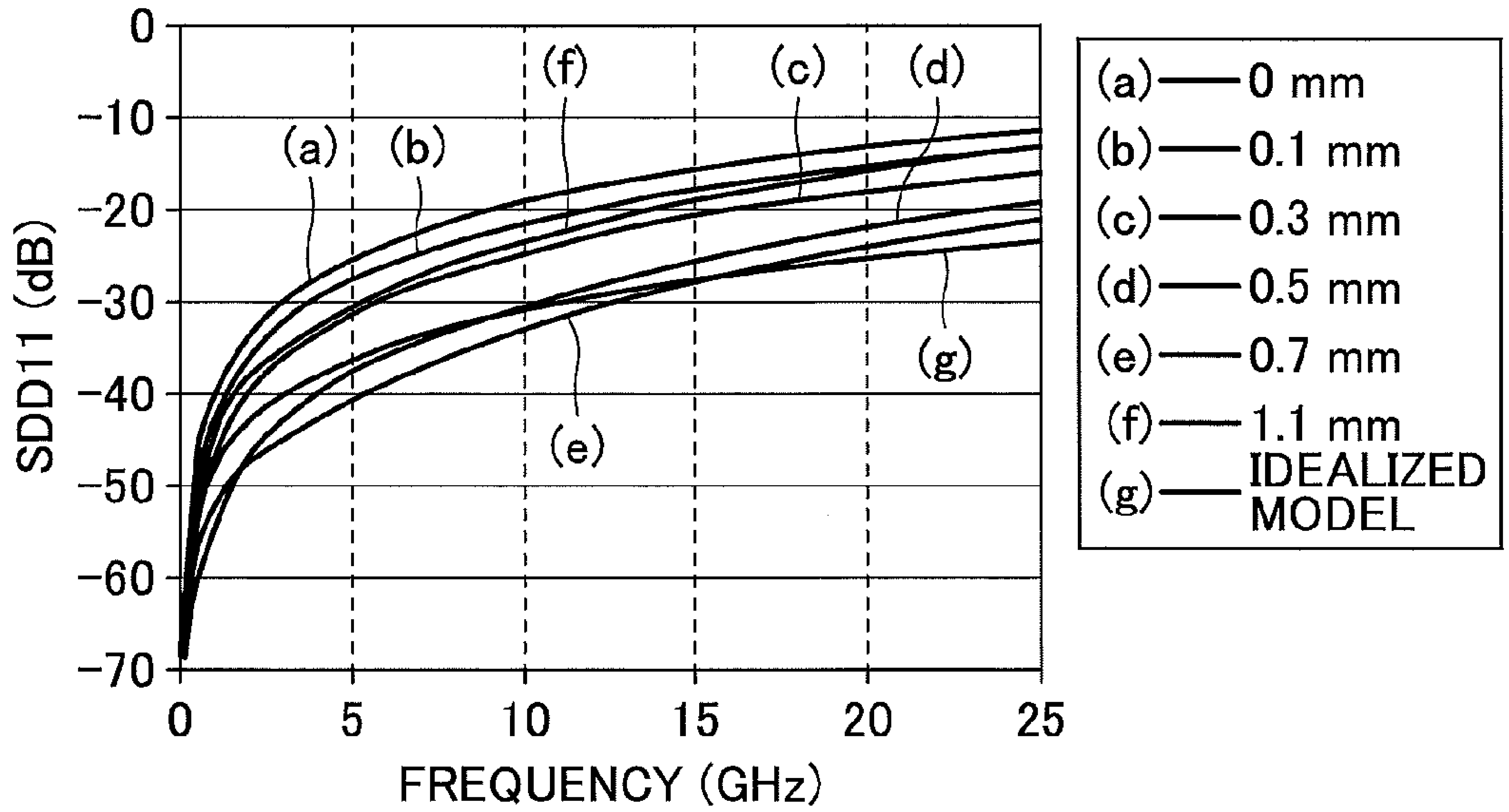

0
−10
−20
−30
−40
−50
−60
−70
SDD11 (dB)
0
5
10
15
20
25
FREQUENCY (GHz)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(a)—0 mm
(b)—0.1 mm
(c)—0.3 mm
(d)—0.5 mm
(e)—0.7 mm
(f)—1.1 mm
(g)—IDEALIZED MODEL

FIG.4B

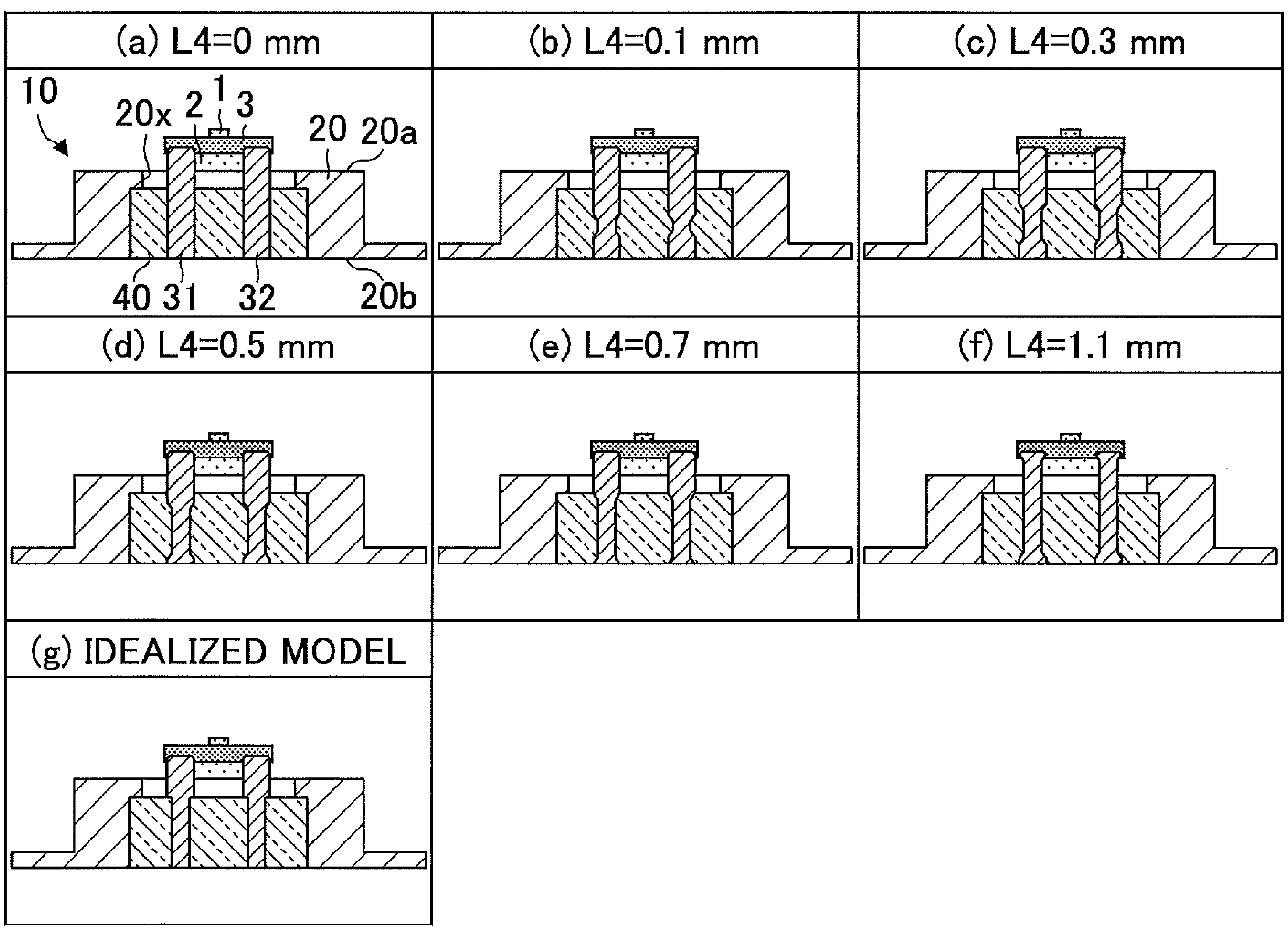

(a) L4=0 mm
(b) L4=0.1 mm
(c) L4=0.3 mm
10
20x
2
1
3
20
20a
40
31
32
20b
(d) L4=0.5 mm
(e) L4=0.7 mm
(f) L4=1.1 mm
(g) IDEALIZED MODEL

FIG.5A

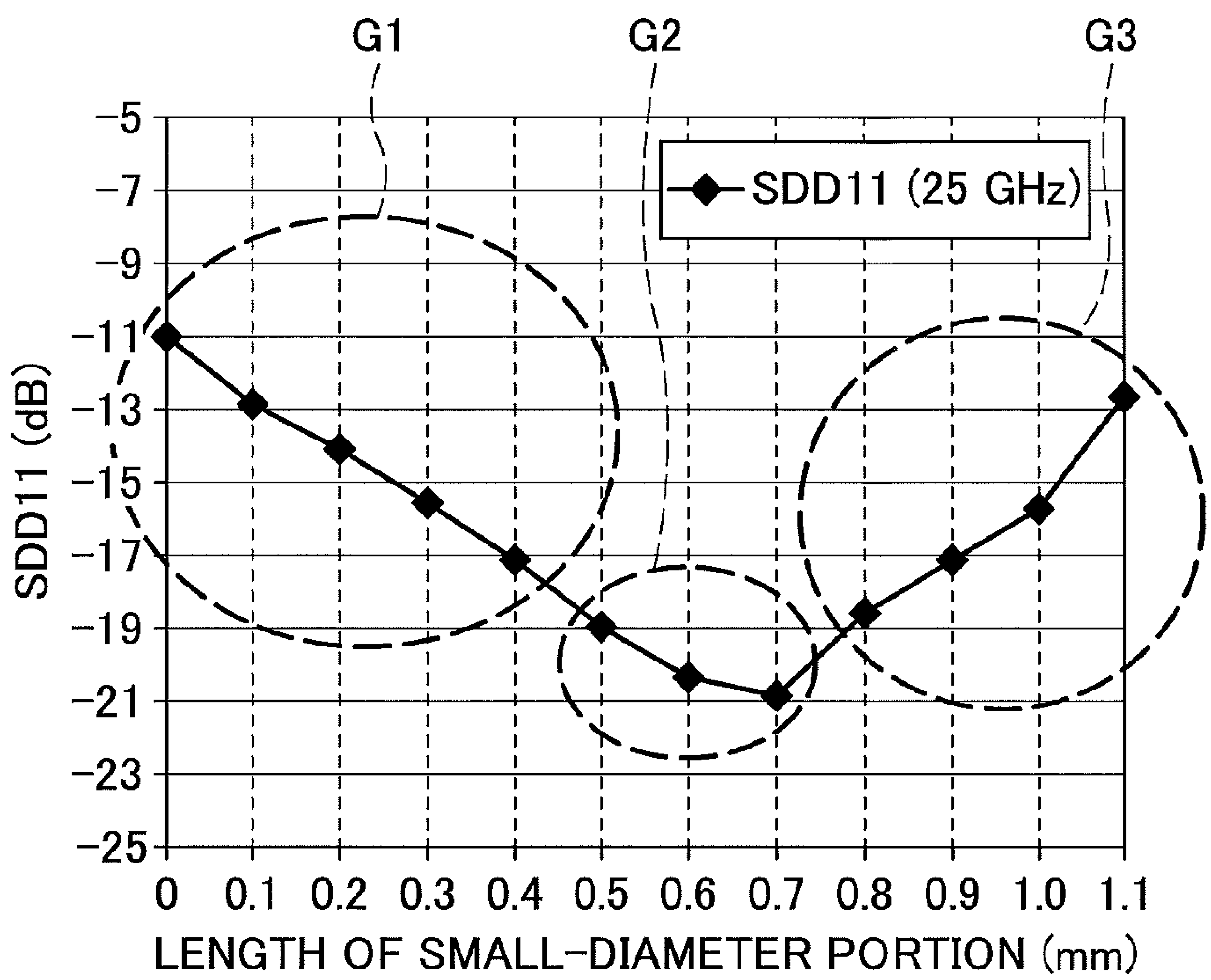

G1
G2
G3
SDD11 (25 GHz)
−5
−7
−9
−11
−13
−15
−17
−19
−21
−23
−25
SDD11 (dB)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
LENGTH OF SMALL-DIAMETER PORTION (mm)

FIG.5B

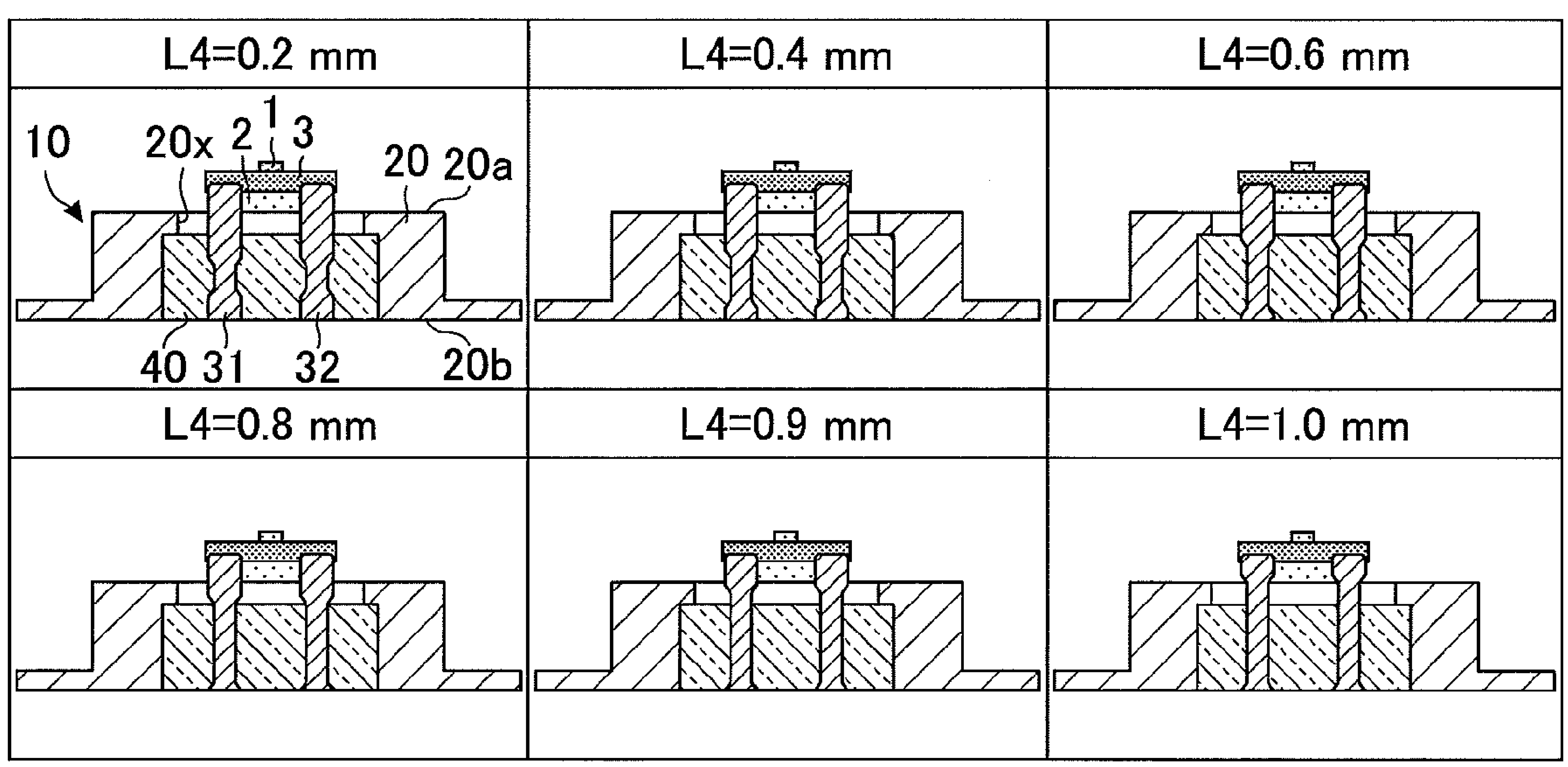
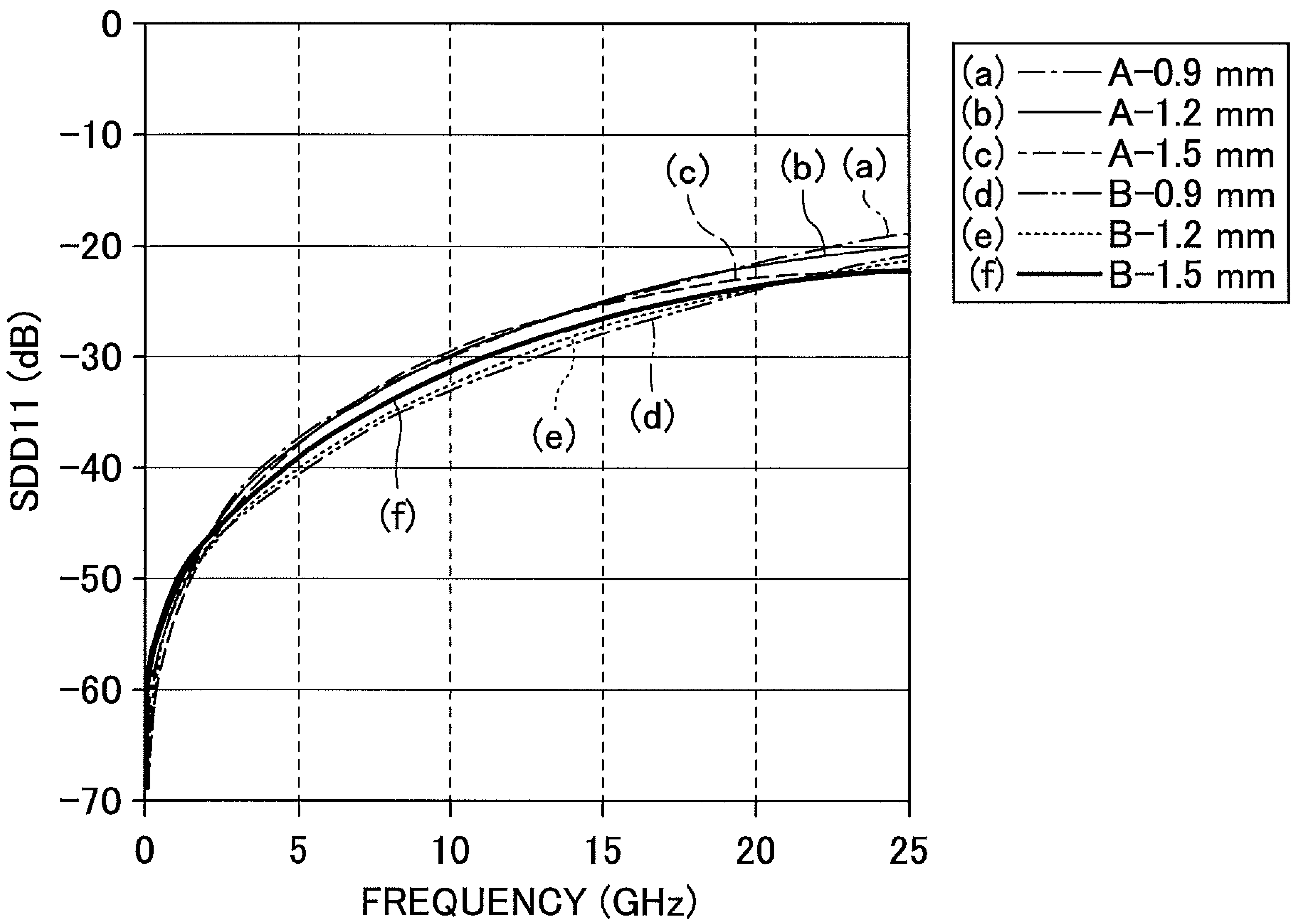

L4=0.2 mm
L4=0.4 mm
L4=0.6 mm
10
20x
2
1
3
20
20a
40
31
32
20b
L4=0.8 mm
L4=0.9 mm
L4=1.0 mm

FIG.6


0
−10
−20
−30
−40
−50
−60
−70
SDD11 (dB)
0
5
10
15
20
25
FREQUENCY (GHz)
(a)
(b)
(c)
(d)
(e)
(f)
(a) A−0.9 mm
(b) A−1.2 mm
(c) A−1.5 mm
(d) B−0.9 mm
(e) B−1.2 mm
(f) B−1.5 mm

# PACKAGE FOR OPTICAL SEMICONDUCTOR DEVICE

## CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2016-002347, filed on Jan. 8, 2016, the entire contents of which are incorporated herein by reference.

## FIELD

A certain aspect of the embodiment discussed herein is related to packages for an optical semiconductor device.

## BACKGROUND

In optical communications, packages for an optical semiconductor device, such as the TO-46 package defined by JEDEC (the JEDEC Solid State Technology Association), are employed as packages for mounting a surface-emitting laser or a photodiode. According to common packages for an optical semiconductor device, leads (terminal parts) are inserted through holes formed through the package and are sealed with glass. Furthermore, according to packages for an optical semiconductor device, the characteristic impedance of a lead is matched to, for example, 50Ω per terminal to prevent a decrease in the efficiency of signal transmission during high-speed communications.

In packages for an optical semiconductor device, spatial restriction makes it difficult to enlarge a hole for inserting a lead to match the impedance per terminal to 50Ω. Therefore, consideration is given to decreasing the dielectric constant of sealing glass and reducing the wire diameter of a lead.

Reducing the wire diameter of a lead, however, not only makes the lead easily bendable but also prevents an area for wire boding from being created at the upper end of the lead. While the lead may be processed into a so-called "nail lead" that is wider at the upper end, the small wire diameter of the lead makes it difficult to perform stable processing.

Thus, there is a limit to the reduction of the wire diameter of a lead. Therefore, studies have been made of designing the shape of a lead to reduce the wire diameter in part of the lead.

Reference may be made to, for example, Japanese Laid-open Patent Publication No. 2009-105284 for related art.

## SUMMARY

According to an aspect of the present invention, a package for an optical semiconductor device includes an eyelet, a signal lead inserted in a through hole formed in the eyelet, and sealing glass sealing the signal lead in the through hole. The signal lead includes a first portion, a second portion and a third portion that are greater in diameter than the first portion and on opposite sides of the first portion, a first tapered portion extending from the second portion to the first portion, and a second tapered portion extending from the third portion to the first portion. The first portion and the first and second tapered portions are buried in the sealing glass. The total length of a part of the second portion in the sealing glass and a part of the third portion in the sealing glass is 0.2 mm or less.

The object and advantages of the embodiment will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and not restrictive of the invention, as claimed.



## BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1**A and **1**B are diagrams depicting a package for an optical semiconductor device according to an embodiment;

FIG. **2** is a diagram illustrating the shape of a first lead and a second lead and the positional relationship between the first and second leads and sealing glass;

FIGS. **3**A and **3**B are diagrams illustrating the shape of the first and second leads and the positional relationship between the first and second leads and the sealing glass;

FIGS. **4**A and **4**B illustrate a reflection characteristic of the package according to the embodiment;

FIGS. **5**A and **5**B illustrate the reflection characteristic of the package according to the embodiment; and

FIG. **6** is a graph illustrating the reflection characteristic of the package according to the embodiment.

## DESCRIPTION OF EMBODIMENTS

In designing the shape of a lead, it is desired to give sufficient consideration to mass productivity. For example, forming a step in a lead to reduce the wire diameter in part of the lead, which is feasible in the case where cutting is employed as a processing technique, is not practical in the case of employing stamping as a processing technique in view of mass productivity. This is because by stamping, it is difficult to provide the lead with a step where portions different in wire diameter are directly adjacent to each other.

Furthermore, in designing the shape of a lead, sufficient consideration has not been given to the reflection characteristic due to impedance mismatch.

According to an aspect of the present invention, a package for an optical semiconductor device with good mass productivity and a good reflection characteristic is provided.

One or more preferred embodiments of the present invention will be explained with reference to accompanying drawings. In the drawings, the same element is referred to using the same reference numeral, and a repetitive description thereof may be omitted.

First, a structure of a package for an optical semiconductor device according to an embodiment is described with reference to FIGS. **1**A and **1**B. FIG. **1**A is a perspective view of the package according to this embodiment. FIG. **1**B is a cross-sectional view of the package, taken along the line A-A of FIG. **1**A.

Referring to FIGS. **1**A and **1**B, a package **10** for an optical semiconductor device (hereinafter, "package **10**") according to this embodiment includes an eyelet **20**, leads **30**, sealing glass **40**, and sealing glass **50**.

The eyelet **20** is a substantially disk-shaped part, and is increased in diameter to form a circular flange at its lower end. Part of a peripheral surface of the eyelet **20** is depressed toward the center of the eyelet **20** to form a depression **20***d*. In a plan view, the depression **20***d* has, for example, a substantial V shape, and may be used to, for example, position a light-emitting device relative to the package **10** when mounting the light-emitting device on the package **10**.

The eyelet **20** may be formed of a metal material such as kovar (a nickel-cobalt ferrous alloy) or an iron-nickel alloy. A surface of the eyelet **20** may be plated. The eyelet **20** may be manufactured using, for example, a cold forging stamping.

According to embodiments of the present invention, the term "disk-shaped" refers to being of a substantially circular planar shape having a predetermined thickness, irrespective of the size of thickness relative to the diameter. The substantially circular planar shape may be partly depressed or projecting.

The leads **30** include a first lead **31**, a second lead **32**, a third lead **33**, a fourth lead **34**, and a fifth lead **35**.

The first lead **31** and the second lead **32** are signal leads. The first lead **31** and the second lead **32** are inserted in a through hole **20***x* (elongated hole) that pierces through the eyelet **20** in its thickness direction, with a longitudinal direction of the first and second leads **31** and **32** coinciding with the thickness direction of the eyelet **20**. The sealing glass **40** is provided around the first lead **31** and the second lead **32** to seal the first and second leads **31** and **32**. The wire diameter of the first lead **31** and the second lead **32** is as described below. The first lead **31** and the second lead **32** have respective upper ends projecting upward approximately 0 mm to approximately 0.05 mm from an upper surface **20***a* of the eyelet **20**. The first lead **31** and the second lead **32** have respective lower ends projecting downward approximately 6 mm to approximately 20 mm from a lower surface **20***b* of the eyelet **20**.

The first lead **31** and the second lead **32** are formed of a metal such as kovar (a nickel-cobalt ferrous alloy) or an iron-nickel alloy. The first lead **31** and the second lead **32** are configured to have their respective upper ends electrically connected to, for example, a light-emitting device to be mounted on the package **10**. In the case of mounting a light-receiving device as well on the package **10**, the upper ends of the first lead **31** and the second lead **32** may also be electrically connected to the light-receiving device. Furthermore, the number of leads to be connected to a light-emitting device and/or a light-receiving device may be increased.

While the first lead **31** and the second lead **32** may be inserted separately in independent through holes the same as the fourth lead **34** and the fifth lead **35**, the first lead **31** and the second lead **32** are inserted in the same through hole **20***x* to produce a space saving effect.

The third lead **33** is a ground lead. The third lead **33** may have a wire diameter of, for example, approximately 0.35 mm. The third lead **33** is joined to the lower surface **20***b* of the eyelet **20** by, for example, welding, to project downward approximately 6 mm to approximately 20 mm from the lower surface **20***b* of the eyelet **20**, with a longitudinal direction of the third lead **33** coinciding with the thickness direction of the eyelet **20**. The third lead **33** is formed of a metal such as kovar (a nickel-cobalt ferrous alloy) or an iron-nickel alloy. The third lead **33** is joined to the eyelet **20** to be electrically connected to the eyelet **20**. Accordingly, when the third lead **33** is grounded, the eyelet **20** is also grounded.

The fourth lead **34** and the fifth lead **35** are power supply leads. The fourth lead **34** is inserted in a through hole **20***y* that pierces through the eyelet **20** in its thickness direction, with a longitudinal direction of the fourth lead **34** coinciding with the thickness direction of the eyelet **20**. The sealing glass **50** is provided around the fourth lead **34** to seal the fourth lead **34**. The fifth lead **35** is inserted in a through hole **20***z* that pierces through the eyelet **20** in its thickness direction, with a longitudinal direction of the fifth lead **35** coinciding with the thickness direction of the eyelet **20**. The sealing glass **50** is provided around the fifth lead **35** to seal the fifth lead **35**. The fourth lead **34** and the fifth lead **35** may have a wire diameter of, for example, approximately 0.35 mm.



The fourth lead **34** and the fifth lead **35** have respective upper ends projecting upward approximately 0 mm to approximately 0.05 mm from the upper surface **20***a* of the eyelet **20**. The fourth lead **34** and the fifth lead **35** have respective lower ends projecting downward approximately 6 mm to approximately 20 mm from the lower surface **20***b* of the eyelet **20**. The fourth lead **34** and the fifth lead **35** are formed of a metal such as kovar.

The dielectric constant of the sealing glass **40** that seals the first lead **31** and the second lead **32**, which are signal leads, is lower than the dielectric constant of the sealing glass **50** that seals the fourth lead **34** and the fifth lead **35**, which are power supply leads. For example, the dielectric constant of the sealing glass **40** may be adjusted to be lower than the dielectric constant of the sealing glass **50** by causing the sealing glass **40** to contain air bubbles and controlling the amount of air bubbles contained in the sealing glass **40**. The dielectric constant of the sealing glass **40** depends on the quality of a material used for the sealing glass **40** and additives to the sealing glass **40**. Therefore, the amount of air bubbles contained in the sealing glass **40** is suitably determined in accordance with the quality of a material used for the sealing glass **40**, etc. Containing air bubbles in the sealing glass **40** does not decrease the hermeticity of the sealing provided by the sealing glass **40**.

Next, the shape of the first lead **31** and the second lead **32** and the positional relationship between the first and second leads **31** and **32** and the sealing glass **40** are described with reference to FIGS. **2**, **3**A and **33**. While the following description is given, taking the first lead **31** as an example as depicted in FIGS. **2**, **3**A and **33**, the description is also applicable to the second lead **32**.

The first lead **31** includes a large-diameter portion **311**, a tapered portion **312**, a small-diameter portion **313**, a tapered portion **314**, and a large-diameter portion **315**, which are concentrically and monolithically formed by, for example, stamping. In the longitudinal direction of the first lead **31**, the large-diameter portions **311** and **315** are positioned on opposite sides of the small-diameter portion **313** with the tapered portions **312** and **314** interposed between the large-diameter portion **311** and the small-diameter portion **313** and between the large-diameter portion **315** and the small-diameter portion **313**, respectively. In FIGS. **2**, 3A and 3B, the boundary between adjacent portions among the large-diameter portion **311**, the tapered portion **312**, the small-diameter portion **313**, the tapered portion **314**, and the large-diameter portion **315** is indicated by the dotted line for convenience of depiction.

A first (upper) end of the large-diameter portion **311** is a free end to be connected by, for example, a wire, to a light-emitting device to be mounted on the package **10**. The tapered portion **312** extends between a second (lower) end of the large-diameter portion **311** and a first (upper) end of the small-diameter portion **313**. The tapered portion **312** is tapered toward the small-diameter portion **313**. The tapered portion **314** extends between a second (lower) end of the small-diameter portion **313** and a first (upper) end of the large-diameter portion **315**. The tapered portion **314** is tapered toward the small-diameter portion **313**. A second (lower) end of the large-diameter portion **315** is a free end. The large-diameter portion **311**, the tapered portion **312**, the small-diameter portion **313**, the tapered portion **314**, and the large-diameter portion **315** form a monolithic structure.

Thus, the tapered portions **312** and **314** are provided at points where the wire diameter changes, that is, the tapered portions **312** and **314** are inserted between portions having different wire diameters, to gradually change the wire diameter. As a result, it is possible to obtain a highly mass-productive and reliable lead without sacrificing the reflection characteristic. Here, it is assumed that no tapered portion is provided at a changing point of the wire diameter so that the wire diameter suddenly changes at the step-shaped changing point in the lead. Such a lead may be manufactured by cutting, but is difficult to manufacture using stamping in view of mass productivity. That is, in the case of stamping, when forging processes such as drawing and swaging are performed in a die (or between dies), a lubricant may deposit at the corner (edge) of a step-shaped portion of the die to prevent a raw material from flowing well into the die. This makes it difficult to shape a lead as desired, so that the shape stability of manufactured leads becomes poor. Furthermore, the load on the die increases.

Furthermore, in the case of applying a stress to a portion of a lead where the wire diameter changes, the stress may concentrate on the portion and cause the lead to bend. Furthermore, in the case of forming the sealing glass **40** with different kinds of materials having different coefficients of thermal expansion and sealing a lead with the sealing glass **40**, a stress concentrates on a portion of the sealing glass **40** near the corner of a step-shaped portion of the lead, so that a crack or the like is likely to be caused in the portion of the sealing glass **40**. In addition, it is likely that, in the portion of the sealing glass **40** near the corner portion of the step-shaped portion of the lead, incorporated air bubbles cannot escape so that air bubbles different from air bubbles intentionally contained in the sealing glass **40** are generated as so-called "captured air bubbles."

These problems can be solved by providing the tapered portions **312** and **314** at the changing points of the wire diameter.

The large-diameter portions **311** and **315** may have a wire diameter of, for example, approximately 0.35 mm. The small-diameter portion **313** may have a wire diameter of, for example, approximately 0.21 mm. Each of the tapered portions **312** and **314** may have a length L**3** of, for example, approximately 0.1 mm. The taper angle of the tapered portions **312** and **314** is preferably 45 degrees or less, and may be, for example, approximately 35 degrees.

Each of the small-diameter portion **313**, the tapered portion **312**, and the tapered portion **314** is positioned in its entirety, that is, buried, in the sealing glass **40**. Furthermore, the total of a length L**1** of a part of the large-diameter portion **311** in the sealing glass **40** and a length L**2** of a part of the large-diameter portion **315** in the sealing glass **40** is 0.2 mm or less. For example, as depicted in FIG. **3**A, the length L**1** may be 0.1 mm and the length L**2** may be 0.1 mm. As another example, as depicted in FIG. **3**B, the length L**1** may be 0 mm and the length L**2** may be 0 mm. In this case, no parts of the large-diameter portions **311** and **315** are present or buried in the sealing glass **40**. That is, the large-diameter portions **311** and **315** are exposed in their entirety outside the sealing glass **40**. FIGS. **3**A and **3**B, however, depict non-limiting examples, and the length L**1** and the length L**2** may be any values that satisfy the condition of L**1**+L**2**≤0.2 mm. The length L**1** and the length L**2** may be different values.

The reason to satisfy L**1**+L**2**≤0.2 mm in the first lead **31** and the second lead **32** is that it is possible to reduce reflections due to impedance mismatch in the sealing glass **40** and impedance mismatch in air. By reducing reflections due to impedance mismatch, an impedance value for high-speed communications may be designed to be a specific value, taking other conditions into consideration. For example, in the case of using the first lead **31** and the second lead **32** for differential transmission, it is possible to approximate the differential impedance to 100Ω (50 Ω+50Ω). As a result, it is possible to realize the package **10** having good transmission characteristics. Here, the "other conditions" include the size of the through hole **20***x*, the wire diameter of the first lead **31** and the second lead **32**, and the dielectric constant of the sealing glass **40**.

The reason to satisfy L**1**+L**2**≤0.2 mm is described in more detail below through examples (simulations).

## EXAMPLES

[Simulation 1]

The reflection characteristic, which is an important electrical characteristic, is simulated with respect to the case of using the first lead **31** and the second lead **32** having the shape as depicted in FIGS. **1**A, **1**B and **2** for differential transmission. The target value of the impedance of the first lead **31** and the second lead **32** is set to 100 Ω (50 Ω+50 Ω because of use for differential transmission), and the conditions of the first lead **31** and the second lead **32**, such as dimensions, are determined as described below.

Specifically, in the configuration as depicted in FIGS. **1**A, **13** and **2**, the length (thickness) of the sealing glass **40** is set to 0.9 mm, the dielectric constant of the sealing glass **40** is set to 4.4, the width of the through hole **20***x* (the dimension of the through hole **20***x* in a direction perpendicular to its longitudinal direction in a plan view) is set to 1.2 mm, the wire diameter of the large-diameter portions **311** and **315** is set to 0.35 mm, the wire diameter of the small-diameter portion **313** is set to 0.21 mm, the length L**3** of the tapered portions **312** and **314** is set to 0.1 mm, and the taper angle of the tapered portions **312** and **314** is set to 35 degrees, and the reflection characteristic in the case of varying a length L**4** of the small-diameter portion **313** from 0 mm to 1.1 mm in a stepwise manner is examined.

The same simulation is also performed with respect to an idealized model. Here, the "idealized model" refers to a model having a stepped shape without the tapered portions **312** and **314** between the large-diameter portions **311** and **315** and the small-diameter portion **313**. The shape of the idealized model is ideal when the electrical characteristics are considered, but is not suitable for actual processing using a die or dies as described above. In contrast, the shape having the tapered portions **312** and **314** is suitable for actual processing using a die or dies.

The results are presented in FIG. **4**A. The horizontal axis of FIG. **4**A represents frequency (GHz), and the vertical axis of FIG. **4**A represents SDD11 (dB). SDD11 is an index that indicates a reflection characteristic under the differential end condition. A smaller SDD11 value is more preferable at each frequency.

FIG. **4**B schematically illustrates the length L**4** of the simulated small-diameter portion **313**. Each model assumes that a light-emitting device is connected to leads. According to the actual structure, the first lead **31** and the second lead **32** are connected to a light-emitting device **1** by bonding wires, while in the simulation models, an analytical structure for clearly indicating the influence exerted on the reflection characteristic by the structural difference of the first lead **31** and the second lead **32**, omitting the influence of bonding wires on the reflection characteristic, is employed.

Specifically, a submount **2** on which the light-emitting device **1** is mounted is mounted on the eyelet **20**. The upper ends of the first lead **31** and the second lead **32** are connected to a perfect conductor sheet **3**, and the perfect conductor sheet **3** is connected to the light-emitting device **1**. Furthermore, the light-emitting device **1** is a perfect conductor model, and is grounded the same as the eyelet **20**. While being depicted in FIG. **4**B for convenience of description, the light-emitting device **1** is actually on the bottom side of the cross sections depicted in FIG. **4**B (the same as the cross section of FIG. **1**B) in the direction going into the plane of paper (that is, on the center side of the eyelet **20**) with the submount **2** extending in the direction going into the plane of paper.

FIG. **4**A demonstrates that the reflection characteristic improves as the length L**4** of the small-diameter portion **313** changes from 0 mm to 0.7 mm. The reflection characteristic, however, degrades when the length L**4** of the small-diameter portion **313** is 1.1 mm. It is believed that this is because the small-diameter portion **313** projects into the air so that an increase in the differential impedance in the air becomes more dominant to cause a high impedance mismatch.

Furthermore, FIG. **4**A demonstrates that when the length L**4** of the small-diameter portion **313** is in the range of 0.5 mm to 0.7 mm with the length of the sealing glass **40** being 0.9 mm, it is possible to obtain the reflection characteristic close to that of the idealized model up to a high-frequency range. Furthermore, it is understood from FIG. **4**A that the change of the reflection characteristic is subject to the difference of the length L**4** of the small-diameter portion **313** in the sealing glass **40** and that the influence of the presence or absence of the tapered portions **312** and **314** on the change of the reflection characteristic is limited.

Next, the data at a frequency of 25 GHz in the results of FIG. **4**A are plotted with respect to each length L**4** of the small-diameter portion **313** in the graph of FIG. **5**A. That is, the horizontal axis of the graph of FIG. **5**A represents the length L**4** (mm) of the small-diameter portion **313**, and the vertical axis of the graph of FIG. **5**A represents SDD11 (dB). Furthermore, the graph of FIG. **5**A also includes the data of the samples depicted in FIG. **5**B.

As indicated in FIG. **5**A, the impedance mismatch is divided into three Groups G**1** through G**3**, and the importance of characteristic impedance matching in each of the sealing glass **40** and air can be confirmed. Group G**1** is a group where the reflection due to impedance mismatch in the sealing glass **40** is dominant. Group G**3** is a group where the reflection due to impedance mismatch in air is dominant. In contract, Group G**2** is a group that is lower in impedance mismatch in the sealing glass **40** and air than Groups G**1** and G**3** to present a good characteristic impedance.

Here, a threshold (the target reflection characteristic of SDD11) for determining whether the impedance mismatch is high or low is set to −19 dB, which is an indication of the characteristic commercially required for packages for an optical semiconductor device.

It is found from FIG. **5**A that when the threshold (the target reflection characteristic of SDD11) is −19 dB, the length L**4** of the small-diameter portion **313** has to be 0.5 mm to 0.7 mm with respect to the length of 0.9 mm of the sealing glass **40**. Here, subtracting the total length of 0.2 mm of the tapered portions **312** and **314** from the length of 0.9 mm of the sealing glass **40** results in a remainder of 0.7 mm. Accordingly, it can be said that the target reflection characteristic cannot be obtained unless the permissible length of the impedance mismatch portion (the total length of the parts of the large-diameter portions **311** and **315** in the sealing glass **40**) is set to 0.2 mm or less.

[Simulation 2]

Next, the influence of the length of the sealing glass **40** is examined. First, the two samples depicted in FIGS. **3**A and **3**B, namely a sample in which the length of the impedance mismatch portion (the total length of the parts of the large-diameter portions **311** and **315** in the sealing glass **40**) is 0.2 mm and a sample in which the length of the impedance mismatch portion is 0 mm, are prepared. With respect to each sample, the length of the sealing glass **40** is changed from 0.9 mm to 1.2 mm to 1.5 mm, and the influence of the change of the length is exampled.

The length of 1.2 mm and the length of 1.5 mm are dimensions commonly employed for glass-sealed packages for a semiconductor device. Furthermore, in the case of the length of 0.9 mm, 0.2 mm of the glass-sealed portion of a package for a semiconductor device in which the glass-sealed portion is supposed to be 1.1 mm in length is not sealed with glass, with a view to matching the differential impedance to 100Ω with an air layer and also increasing an area for mounting, for example, a laser or a photodetector.

The results are presented in FIG. **6**. The horizontal axis of the graph of FIG. **6** represents frequency (GHz) and the vertical axis of the graph of FIG. **6** represents SDD11 (dB). Furthermore, A-0.9 mm, A-1.2 mm, and A-1.5 mm indicate the data of a group where the length of the impedance mismatch portion is 0.2 mm (hereinafter, "Group A"), and B-0.9 mm, B-1.2 mm, and B-1.5 mm indicate the data of a group where the length of the impedance mismatch portion is 0 mm (hereinafter, "Group B").

It can be confirmed from FIG. **6** that while the reflection characteristic slightly differs between Group A and Group B, in general, the reflection characteristic is hardly affected by the length of the sealing glass **40**.

## Experiment 1

It was determined, with respect to the first lead **31** and the second lead **32** of the shape depicted in FIGS. **1**A, **1**B and **2**, whether air bubbles other than those originally contained were generated near the tapered portions **312** and **314** in the sealing glass **40** in the case of causing air bubbles to be contained in the sealing glass **40**. The experiment was conducted with respect to ten samples, and no generation of air bubbles was observed in any of the samples. Furthermore, no glass cracks were caused near the tapered portions **312** and **314** in any of the samples.

## Experiment 2

A cap with window glass was welded onto the eyelet **20** of the package **10** as depicted in FIGS. **1**A and **1**B by electric resistance welding. Air bubbles were contained in the sealing glass **40**. Next, the package **10** on which the cap was welded was left in an environment of a temperature of 121° C., a humidity of 100%, and an atmospheric pressure of 2 atm for 280 hours, and the presence or absence of moisture penetration into the cap was determined through the window glass. The experiment was conducted with respect to ten samples, and no moisture penetration was observed in any of the samples. That is, it was confirmed that containing air bubbles in the sealing glass **40** does not decrease the hermeticity of the sealing provided by the sealing glass **40**.

## SUMMARY

To sum up the results of Simulations 1 and 2 described above, the following points carry weight to improve the reflection characteristic.

First, it is preferable that each of the small-diameter portion **313**, the tapered portion **312**, and the tapered portion **314** be buried in the sealing glass **40**.

Secondly, it is more preferable that the small-diameter portion **313**, which is buried in the sealing glass **40**, is longer, and it is more preferable that a shorter part of each of the large-diameter portions **311** and **315** is in the sealing glass **40**. Taking the required reflection characteristic into consideration, the permissible total length of the parts of the large-diameter portions **311** and **315** in the sealing glass **40** is 0.2 mm or less, independent of the length of the sealing glass **40**.

Thirdly, the length of the small-diameter portion **313** buried in the sealing glass **40** is dominant, and the influence of the presence or absence of the tapered portions **312** and **314** is limited.

All examples and conditional language provided herein are intended for pedagogical purposes of aiding the reader in understanding the invention and the concepts contributed by the inventors to further the art, and are not to be construed as limitations to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority or inferiority of the invention. Although one or more embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

For example, while two signal leads are inserted in a single hole according to the above-described embodiment, a single signal lead may alternatively be inserted in a single hole. Furthermore, while two signal leads are used for differential transmission according to the above-described embodiment, two signal leads may alternatively be used independent of each other. In addition, the number of leads included in a package for an optical semiconductor device may be determined as desired. In any of these cases, it is possible to achieve a good reflection characteristic by satisfying the above-described conditions.

What is claimed is:

**1**. A package for an optical semiconductor device, comprising:

an eyelet;

a signal lead inserted in a through hole formed in the eyelet; and

sealing glass sealing the signal lead in the through hole,

wherein the signal lead includes

a first portion;

a second portion and a third portion that are greater in diameter than the first portion and on opposite sides of the first portion; and

a first tapered portion extending from the second portion to the first portion and a second tapered portion extending from the third portion to the first portion,

wherein the first portion and the first and second tapered portions are buried in the sealing glass, and

wherein a total length of a part of the second portion in the sealing glass and a part of the third portion in the sealing glass is 0.2 mm or less.

**2**. The package as claimed in claim **1**, wherein the sealing glass contains air bubbles.

**3**. The package as claimed in claim **1**, further comprising:

another signal lead inserted in the through hole, said another signal lead having a same configuration as the signal lead,

wherein the sealing glass further seals said another signal lead in the through hole.

**4**. The package as claimed in claim **1**, wherein the total length is 0 mm or more.

**5**. The package as claimed in claim **1**, wherein the second portion and the third portion are partly or entirely exposed outside the sealing glass.

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